Lab 6. Antennas

Name: ______________________________

Section: ______________________________

Complete and turn in this booklet by the end of the lab period!
(No late submissions will be accepted)

Task 11. Antenna for "Radio City"

Congratulations!!! You have just graduated from Penn State with a degree in Electrical Engineering and have landed a job with the prestigious radio station *Radio City – 90.1FM.* As your first assignment, you are to work on a team to set up their newest radio station for the *Meadows* near Las Vegas, NV.

As shown in Fig. 1, Radio City has bought a small plot of land (the red spot north of the city) just outside the city and hopes to provide service to all of Las Vegas while conserving power by not having their signal transmitted to the surrounding desert and the National Wildlife Refuge. The radio station uses half-wave center-driven dipole antennas to transmit the 90.1-MHz radio signal.

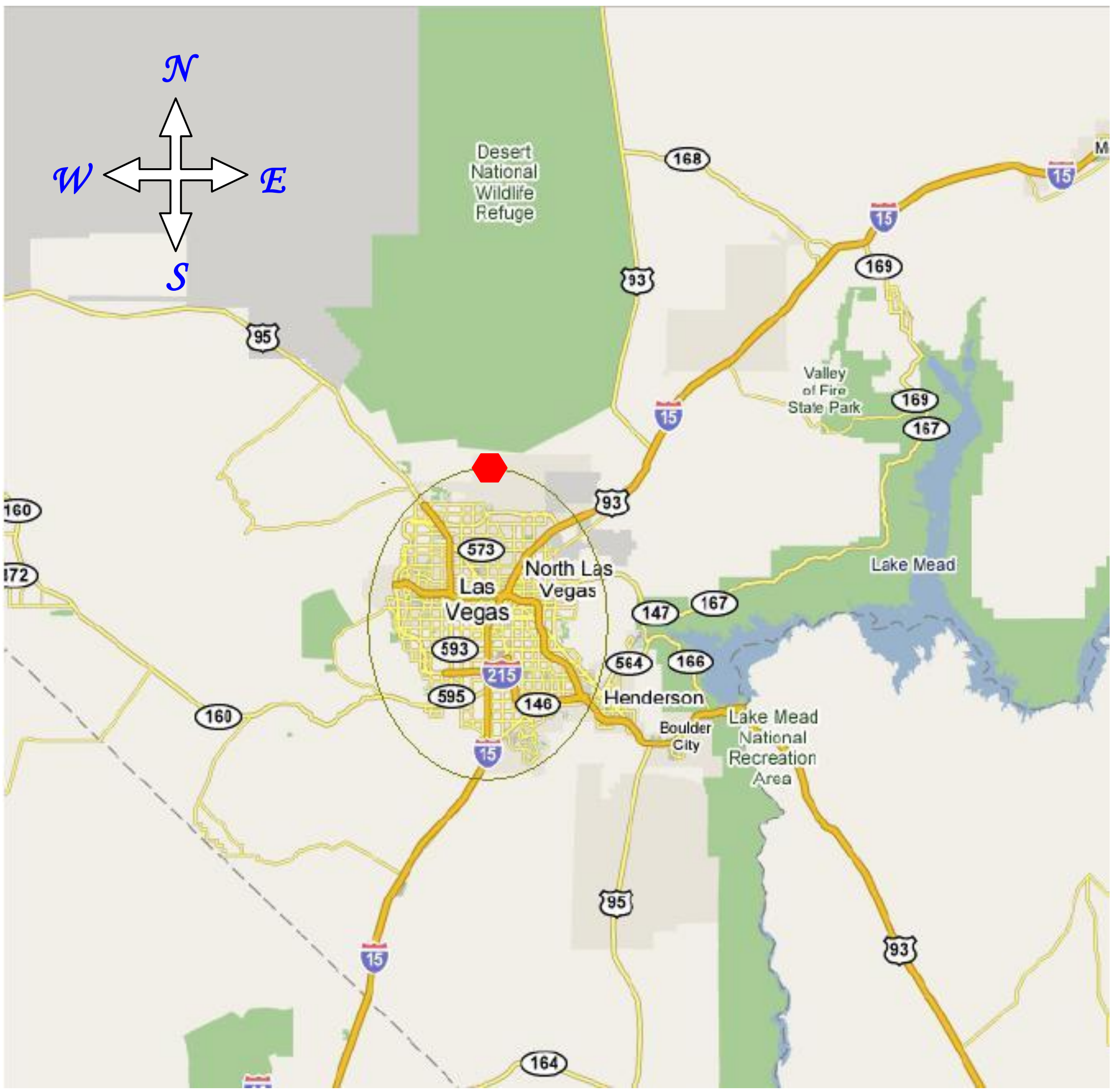

Fig. 1. Expected area of coverage for the radio transmission

Assignment

You think back to your EE 330 class where you learned how using multiple antennas in a linear array pattern can be used to achieve concentration of signal in certain directions by producing nulls at appropriate angles and nodes at others. You know that at least two antennas are necessary in order to achieve your goal. Therefore, you are to simulate the radiation pattern for the case of two identical antennas that form a uniform linear array and determine whether such an array will work for you. To do so, you first decide on the array parameters and orientation.

The two antenna elements must be oriented vertically (along the *z* axis) and positioned on the *y* axis, as denoted on the figure to the right with black circles. This choice ensures that the radiation pattern can be made asymmetrical in North-South direction.

About an hour after you have received the task, you report to your manager. He is delighted with the quality of your work and the promptness you've demonstrated. A month later, the city of Las Vegas is thankful to you for being able to listen to Radio City – 90.1FM.

Fig. 2

To complete the assignment:

1. Answer the first 7 question in the Task Report Questionnaire.
2. In your analysis, impose two requirements:

   (a) No radiation towards the National Wildlife Refuge;

   (b) Maximum radiation towards the city.

WARNING: Since you must complete the lab while in class, do not proceed further without having your TA or instructor check your answers to questions 6 and 7.

3. Use the provided MATLAB code template to plot the radiation pattern of the two-element array antenna in the horizontal plane. Use the user contributed function *mmpolar*. Make sure this function is in your current MATLAB directory. Print out the plot.
4. In answering question 8, note that according to the FCC standards, the signal must be at least 25 mV/m to ensure good quality of signal reception within the coverage area. Assume the city is 36 km long in North-South direction and 27 km wide in East-West direction.
5. To do the work related to the last two questions in the Task Report Questionnaire, use the following information, which generalizes the case of a linear uniform array antenna to an arbitrary number of antenna elements.

The E-field generated by a linear uniform array antenna having N antenna elements is the product of the field due to a single antenna element, E_e, and the **field** array factor, $F_{Ea}(\theta,\varphi)$, that accounts for the presence of the other antenna elements:

$$E_{\text{total}} = E_{\text{e}}(R,\theta)F_{Ea}(\theta,\varphi),$$

where $$F_{Ea}(\theta,\varphi) = \frac{\sin\left[N\left(\dfrac{kd\sin\theta\sin\varphi+\psi}{2}\right)\right]}{\sin\left(\dfrac{kd\sin\theta\sin\varphi+\psi}{2}\right)} e^{j(N-1)\left(\frac{kd\sin\theta\sin\varphi+\psi}{2}\right)}.$$

The corresponding power density is also the product of two factors, namely, the power density due to one antenna element, S_e, and the array factor, $F_a(\theta,\varphi)$:

$$S = S_{\text{e}}(R,\theta)F_a(\theta,\varphi)$$

where the array factor is the squared magnitude of the field array factor, $F_a(\theta,\varphi) = |F_{Ea}(\theta,\varphi)|^2$

6. Print out the plots for questions 9 and 10.
7. Staple all the printouts (see steps 3 and 6 above) to this booklet and hand the paper in by the end of the class period. NO LATE SUBMISSIONS WILL BE ACCEPTED!
8. **Show all your work, to receive full credit.**

<u>Suggested MATLAB code template:</u>

```
% Task #11: Antenna for "Radio City"
% Polar plot of the radiation pattern in the azimuth plane. Array of 2 half-
wave dipoles
clear all; figure;
lambda=        ; % Wavelength in meters
d=             ; % Distance between the two antenna elements
psi=           ; % Phase difference between the driving currents
phi=0:0.01:2*pi; % Azimuth angle ranges from 0 to 2pi
Sn=            ; % Radiation pattern (make sure this is the NORMALIZED power
density)
mmpolar(phi,Sn,'tzerodirection','???','tdirection','ccw','tticklabel',{'0','1
5','30','45','60','75','90','105','120','135','150','165','180','195','210','
225','240','255','270','285','300','315','330','345'}) % Plots a polar plot
```

In `mmpolar`, replace ??? with the direction (east, south, west, or north) corresponding to zero azimuth angle according to the given choice of coordinate system and spatial arrangement of the antenna elements.

Task 11. Antenna for "Radio City"

Questionnaire

Give brief but accurate and thorough explanation if necessary. Provide math expressions where needed to show how you've obtained the particular result.

1. What is the physical length of each of the antennas you are employing in the array?

2. According to the given choice of coordinate system, what are the angular coordinates of the center of the city (i.e., the elevation angle θ = ? and the azimuth angle ϕ = ?)

3. Impose the requirement of no radiation towards the National Wildlife Refuge and give the equation it leads to.

4. Impose the requirement of maximum radiation towards the city and give the equation it leads to.

5. Simultaneously solve the equations from questions 3 and 4 to obtain sets of possible values for the current phase shift, ψ, and the distance between the antenna elements, d. Show your work.

6. What is your choice for the current phase shift and the distance between the antenna elements?

7. Give the expression to be used for plotting the radiation pattern in the azimuth plane of the antenna array. After obtaining the approval of your TA, print out the plot and staple it to this booklet.

8. What is the driving current amplitude that is needed to maintain the FCC standards when the two-element antenna is used? Provide both the math expression and the value.

9. By answering the previous questions, you've proved that a two-element antenna can be successfully employed. One way to further improve the signal focusing in a given direction is by increasing the number of antenna elements in the array. Using MATLAB, observe and plot the radiation pattern in the azimuth plane for **five (5)** antenna elements. Assume the same distance between the elements and the same phase shift between the driving currents as in the case of two elements. Comment on how this pattern compares to the pattern of the two-element antenna and its suitability to the needs of Radio City in Las Vegas.

10. Using MATLAB, observe and plot the radiation pattern in the azimuth plane for **twenty (20)** antenna elements. Assume the same distance between the elements and the same phase shift between the driving currents as in the case of two elements. Comment on how this pattern compares to the pattern of the two-element antenna and its suitability to the needs of Radio City in Las Vegas.